The present invention describes a method of casting a metal alloy comprising forming a sand based mold having the geometry to generate a desired object to be cast, placing the mold in an open pressure vessel, filling the mold with a molten metal alloy, immediately thereafter closing and pressure sealing the pressure vessel, pressurizing the sealed pressure vessel with an inert gas for a measured time said predetermined measured time sufficient for the molten metal to cool and fully solidify, depressurizing the sealed pressure vessel and removing the metal filled sand mold, and extracting the desired object from the mold.
Comparison of Pressure/Atmospheric Variables on Mechanical Properties of A356 T6, Dry Sand Cast (1in+ Section Thickness)

FIG. 5
FIG. 8

Gas/Pressure Cooling Curves

- He 10 atm
- Air 10 atm
- He 1 atm
- Air 1 atm
SAND CASTING DEVICE AND ASSOCIATED
METHOD WITH IMPROVED MECHANICAL
PROPERTIES

CROSS-REFERENCE TO RELATED
APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 62/124,016 filed Dec. 6, 2014, which hereby is incorporated herein in its entirety by reference thereto.

FIELD OF THE INVENTION

[0002] The present invention is directed generally to manufacturing metal objects and more specifically to a device and method to sand cast metal objects.

BACKGROUND

[0003] Sand casting is a metal casting process characterized by using sand as the mold material. The term “sand casting” can also refer to an object produced via the sand casting process. Sand castings are produced in specialized factories commonly referred to as foundries. Sand casting is a relatively inexpensive means to produce common everyday metal objects as well as intricate aerospace and military components. A pattern of the desired object, including the metal delivery gating system, is constructed. A mold in the sand casting process combines sand and a suitable binding agent. The binding agent can be water and clay or alternately compounds that cure after mixing with the sand. The bonding agent enables the aggregate mixture to retain its shape after being compacted against a mold or pattern. The pattern and gating system is commonly bounded by a system of frames or boxes, known as skils, which guide the mold sand to an exterior shape. The pattern is removed from the bonded sand leaving a cavity in the shape of the final object. Sand molds can also be created by compacting the sand and binding agent in a flask and carving the desired mold form and gating directly into the aggregate mixture. Molten metal is then poured into the cavity, and the metal solidifies. The bonded sand is removed from the cast object through a shakeout process. The gating system is trimmed away leaving the desired object. The molding process proceeds generally along the following 6 steps:

[0004] Step #1: Pack sand around a pattern to create a mold cavity.
[0005] Step #2: Incorporate the pattern and sand in a gating system if the gating system is not already provided in the pattern tooling.
[0006] Step #3: Remove the pattern.
[0007] Step #4: Fill the mold cavity with molten metal.
[0008] Step #5: Allow the metal to cool and fully solidify.
[0009] Step #6: Break away the sand mold and remove the cast metal object.

SUMMARY OF THE INVENTION

[0010] The present invention is directed generally to manufacturing cast metal objects and more specifically to a method and device to sand cast metal objects.

[0011] One embodiment of the present invention describes a method of casting a metal alloy comprising the following steps: forming a sand based mold having the appropriate geometry to generate a desired object to be cast, placing the sand based mold in an open pressure vessel, filling the sand based mold with a molten metal alloy, immediately thereafter closing and pressure sealing the pressure vessel, pressurizing the sealed pressure vessel with an inert gas for a predetermined measured time, said predetermined measured time sufficient for the molten metal to cool and solidify, depressurizing the sealed pressure vessel, opening the pressure vessel and removing the metal filled sand mold, and extracting the desired object from the sand mold.

[0012] Another embodiment of the present invention describes a method of casting a metal alloy comprising the following steps: forming a sand based mold having the appropriate geometry to generate a desired object to be cast, placing the sand based mold in an open pressure vessel, filling the sand based mold with a molten metal alloy, immediately thereafter closing and pressure sealing the pressure vessel, pressurizing the sealed pressure vessel with an inert gas for a predetermined measured time, said predetermined measured time sufficient for the molten metal to cool and solidify, withdrawing the inert gas from the sealed pressure vessel and transferring said inert gas into a reusable purification and storage device thereby depressurizing the sealed pressure vessel, opening the pressure vessel and removing the metal filled sand mold, and extracting the desired object from the sand mold.

[0013] An alternative embodiment of the present invention describes a method of casting a metal alloy comprising the following steps: forming a sand based mold having the appropriate geometry to generate a desired object to be cast, placing the sand based mold in an open pressure vessel, immediately thereafter closing and pressure sealing the pressure vessel, pressurizing the sealed pressure vessel with an inert gas for a predetermined measured time, said predetermined measured time sufficient for the molten metal to cool and solidify, withdrawing the inert gas from the sealed pressure vessel and transferring said inert gas into a reusable purification and storage device thereby depressurizing the sealed pressure vessel, opening the pressure vessel and removing the metal filled sand mold, and extracting the desired object from the sand mold.

[0014] Another embodiment of the present invention describes a method to reduce porosity defects in sand casted metal objects comprising the following steps: forming a sand based mold having the appropriate geometry to generate a desired object to be cast, placing the sand based mold in an open pressure vessel, filling the sand based mold with a molten metal alloy, immediately thereafter closing and pressure sealing the pressure vessel, pressurizing the sealed pressure vessel with an inert gas for a predetermined measured time, said predetermined measured time sufficient for the molten metal to cool and solidify, depressurizing the sealed pressure vessel, opening the pressure vessel and removing the metal filled sand mold, and extracting the desired object from the sand mold.

[0015] Another embodiment of the present invention describes a method to reduce porosity defects in sand casted metal objects from mold-metal interface reactions (also referred to as core reactions) comprising the following steps: forming a sand based mold having the appropriate geometry to generate a desired object to be cast, placing the sand based mold in an open pressure vessel, filling the sand based mold with a molten metal alloy, immediately thereafter closing and pressure sealing the pressure vessel, pressurizing the sealed pressure vessel with an inert gas for a predetermined measured time, said predetermined measured time sufficient for the molten metal to cool and solidify, depressurizing the sealed pressure vessel, opening the pressure vessel and removing the metal filled sand mold, and extracting the desired object from the sand mold.
the molten metal to cool and solidify, depressurizing the sealed pressure vessel, opening the pressure vessel and removing the metal filled sand mold, and extracting the desired object from the sand mold.

[0016] Another embodiment of the present invention describes a method to improve the tensile strength, yield strength, and percent elongation of a sand casting comprising the following steps: forming a sand based mold having the appropriate geometry to generate a desired object to be cast, placing the sand based mold in an open pressure vessel, filling the sand based mold with a molten metal alloy, immediately thereafter closing and pressure sealing the pressure vessel, pressurizing the sealed pressure vessel with an inert gas for a predetermined measured time said predetermined measured time sufficient for the molten metal to cool and solidify, depressurizing the sealed pressure vessel, opening the pressure vessel and removing the metal filled sand mold, and extracting the desired object from the sand mold.

[0017] Another embodiment of the present invention describes a device for casting a metal alloy comprising the following elements: a pressure vessel head, a pressure vessel base incorporating a surface to support a sand casting mold, a vertical travel guide in mechanical communication with the pressure vessel head and the pressure vessel base, said pressure vessel head and pressure vessel base incorporating interlocking members capable of forming a pressure seal when interlocked, and an actuator capable of engaging the interlocking members thereby forming a pressure seal when the pressure vessel head is in mechanical communication with the pressure vessel base.

[0018] The above summary of the present invention is not intended to describe each illustrated embodiment or every implementation of the present invention. The figures and the detailed description which follow more particularly exemplify these embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The invention may be more completely understood in consideration of the following detailed description of various embodiments of the invention in connection with the accompanying drawings, in which:

[0020] FIG. 1 shows a schematic representation of a pressure vessel shown in the open configuration. The pressure vessel may be comprised of a pressure vessel head, a vertical travel guide, and a pressure vessel base which is designed to form a pressure seal when in mechanical communication with the pressure vessel head.

[0021] FIG. 2 shows the pressure vessel depicted in FIG. 1 incorporating a sand cast mold mounted on the pressure vessel base.

[0022] FIG. 3 shows the pressure vessel depicted in FIG. 1 in the closed and unlocked, i.e. non-pressurized, configuration.

[0023] FIG. 4 shows the pressure vessel depicted in FIG. 1 in the closed and pressurized configuration while in airway communication with an external source of a pressurized inert gas.

[0024] FIG. 5 summarizes the quantitative results of an experimental protocol consisting of sand casting the same aluminum alloy utilizing a common mold architecture with immediate follow-on pressurized gas treatments.

[0025] FIGS. 6A and 6B are graphical representations comparing the presence of pores (6A elements 602) generated via sand casting under normal atmospheric pressure and the absence of said pores (6B elements 604) when the casting is performed under 10 atmospheres of pressure in accordance with the procedures outlined in the present invention.

[0026] FIGS. 7A and 7B are the untouched photos from which the graphical representations shown in FIGS. 6A and 6B were derived therewith highlighting the pores (7A elements 702) generated via sand casting under normal atmospheric pressure and the absence of said pores (7B elements 704) when the casting is performed under 10 atmospheres of pressure in accordance with the procedures outlined in the present invention.

[0027] FIG. 8 highlights the dramatic increase in the cooling rate of the molten aluminum when cooling under helium at both 1 and 10 atmospheres of pressure as compared to cooling under air at the same pressure ranges.

[0028] While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION

[0029] The present invention is directed generally to manufacturing metal objects and more specifically to a device and method to sand cast metal objects. One embodiment of the present invention is depicted schematically in FIGS. 1 through 4 highlighting the apparatus to pressurize an encased metal filled sand mold with an inert gas.

[0030] FIG. 1 depicts a pressure vessel 10 shown in the open configuration. The pressure vessel 10 may be comprised of a pressure vessel head 12, a vertical travel guide 14, and a pressure vessel base 16 which is designed to form a pressure seal when in mechanical communication with the pressure vessel head 12.

[0031] In one embodiment of the present invention, a sand based mold 20 (see FIG. 2) having the appropriate internal geometry to generate a desired object to be cast may be placed on a planar substrate 18 which is part of the pressure vessel base 16. Once in place, the sand based mold 20 may be filled with a molten metal, preferably an aluminum alloy. Immediately after filling the sand based mold 20 with molten metal, the pressure vessel head 12 may be lowered and placed in mechanical communication with the pressure vessel base 16. In placing the pressure vessel head 12 in mechanical communication with the pressure vessel base 16, care may be taken to align the male interlocking elements 22A adhered to the bottom of the pressure vessel head 12 with the female counterpart interlocking elements 22B adhered to the pressure vessel base 16 as shown in FIG. 3. Once properly aligned, a linear actuator 24 attached to the pressure vessel base 16 may be energized which in turn may interlock the male and female locking elements thereby pressure sealing the pressure vessel.

[0032] Once the pressure seal has been established, an external source of an inert pressurized gas, preferably helium, may be inserted into the pressure sealed vessel by way of a valve 26 incorporated into the wall of the pressure vessel base 16 as depicted in FIG. 4. In one embodiment of the present invention, the inert gas may pressurize the sealed vessel in the range of 50 to 180 pounds per square inch. The sealed, inert gas pressurized vessel may remain pressurized for a prede-
terminated time commensurate with the size of the sand casting mold and the volume of molten metal encased therein to allow the molten metal to cool and fully solidify.

[0033] In a preferred embodiment of the present invention, the pressure vessel and the external source of inert gas may be configured to reclaim and purify for later reuse the inert gas used previously in the process of pressurizing the pressure vessel as described above. During the above said process of reclaiming and purifying the inert gas, other harmful gases and particulate matter generated during the casting process and intermixed with the helium gas may be separated therefrom and sufficiently filtered by means well known to those skilled in the art, and substantially less hazardous by-products may be released back into the atmosphere and hazardous by-products may be appropriately contained.

[0034] In order to demonstrate the utility of the present invention, a prototype apparatus in accordance with the specification and drawings outlined above was configured and utilized to generate a series of sand casted metal objects. The goal of the experimentation was to demonstrate that sand casting followed immediately with gaseous pressure, preferably with helium, would yield a metal object with enhanced mechanical properties over sand casting immediately followed with normal atmospheric pressure or pressurizing with ambient air.

[0035] FIG. 5 summarizes the quantitative results—the experimental protocol consisted of sand casting the same aluminum alloy (A356) utilizing a common mold architecture with immediate follow-on pressurized gas treatment. As shown in FIG. 5, filling the sand mold immediately followed by pressure treatment with helium gas in the range of 1 to 10 atmospheres of pressure yielded a significant improvement in tensile strength, yield strength, and percent elongation over pressure treatment with ambient air in the same pressure range.

[0036] In yet another embodiment of the present invention, to demonstrate efficacy of the finished casting product, the following experimental protocol was followed:

[0037] Step 1: Form a resin coated sand mold with binding agent.

[0038] Step 2: Place the mold within one half of a pressure vessel shell.

[0039] Step 3: C355 aluminum alloy (as depicted in FIG. 6 and FIG. 7) was melted, fluxed, degassed and grain refined.

[0040] Step 4: Molten aluminum was transferred from a furnace via hand ladles and poured into a cup above the sprue.

[0041] Step 5: Upon completion of the pour, the pressure vessel was closed and pressure sealed in approximately 10-12 seconds.

[0042] Step 6: A valve was opened to allow gas to flow into the closed vessel which reached the range of 6 to 7 atmospheres within 12-15 seconds.

[0043] Step 7: The casting was allowed to cool and fully solidify for 10 to 20 minutes.

[0044] Step 8: After solidification, the pressure vessel was depressurized, opened, and the casting was removed from the pressure vessel and allowed to cool to room temperature.

[0045] Step 9: Thereafter the gates were sawed off, sectioned into quadrants, and the cut surfaces were ground. Some parts were polished and others blasted with a fine 180 grit aluminum oxide.

[0046] In a separate experimental step, the same steps were taken as above except that the mold was allowed to cool under normal atmospheric pressure. The comparison results of surface morphology are shown as depicted in FIGS. 6 and 7, FIG. 7 being an unaltered photograph of the finished parts under direct comparison.

[0047] To further demonstrate the advantages of sand casting under pressure, preferably with helium, an additional set of experiments were performed to investigate the accelerated cooling of molten aluminum under helium pressure as compared to normal atmospheric pressure. Cycle time is a critical parameter in a manufacturing process—where decreased cycle time to manufacture a sellable product leads to increased throughput, which in turn leads to increased revenue. FIG. 8 graphically summarizes the results of these experiments.

[0048] As shown in FIG. 8, four discrete sand casting procedures were performed. The experimentation followed closely the 8 step protocol defined above relative to FIG. 5, with the exception that a thermocouple was placed within the sand mold prior to the pouring of molten aluminum, and located in a position to be embedded within the molten aluminum as it fills the sand mold.

[0049] The conclusion from these experiments is quite evident—sand casting with helium either at normal atmospheric pressure or at an elevated pressure in the range of 10 atmospheres significantly increases the rate at which the molten aluminum cools and ultimately solidifies as compared to normal atmospheric air at the same pressure.

[0050] The present invention should not be considered limited to the particular examples described above, but rather should be understood to cover all aspects of the invention as fairly set out in the attached claims. Various modifications, equivalent processes as well as numerous structures to which the present invention may be applicable will be readily apparent to those of skill in the art of casting metal objects. For example, the invention anticipates other geometrical configurations for the pressure vessel including but not limited to a horizontal design in contrast to the vertical configuration outlined in the above description. Also, the present invention anticipates that the time for the molten aluminum to cool and solidify while still encased within the pressure chamber may depend upon the volume of molten aluminum poured and in many cases the ratio of volume-to-surface area of the encased aluminum and one of ordinary skill in the art may make that determination theoretically or by experimentation. The following claims are intended to cover such modifications and devices.

1 claim:

1. A method of casting a metal alloy comprising the following steps:

   forming a sand based mold having the appropriate geometry to generate a desired object to be cast;

   placing the sand based mold in an open pressure vessel;

   filling the sand based mold with a molten metal alloy;

   immediately thereafter closing and pressure sealing the pressure vessel;

   depressurizing the sealed pressure vessel with an inert gas for a predetermined measured time;

   said predetermined measured time sufficient for the molten metal to cool and solidify;

   depressurizing the sealed pressure vessel;
opening the pressure vessel and removing the metal filled sand mold; and
extracting the desired object from the sand mold.
2. The method of claim 1 wherein the sand based mold may be comprised of silica sand (SiO₂), chromite sand (FeCr₂O₄), zircon sand (ZrSiO₄), olivine, staurolite, graphite, bentonite (clay), anthracite, water, organic and inorganic binders, and combinations thereof.
3. The method of claim 1 wherein the inert gas may be helium, argon, nitrogen, oxygen or combinations thereof.
4. The device of claim 1 wherein the sealed pressure vessel is pressurized to a value in the range of 50 to 180 pounds per square inch with the inert gas.
5. A method of casting a metal alloy comprising the following steps:
forming a sand based mold having the appropriate geometry to generate a desired object to be cast;
placing the sand based mold in an open pressure vessel;
filling the sand based mold with a molten metal alloy;
immediately thereafter closing and pressure sealing the pressure vessel;
pressurizing the sealed pressure vessel with an inert gas for a predetermined measured time;
said predetermined measured time sufficient for the molten metal to cool and solidify;
withdrawing the inert gas from the sealed pressure vessel and transferring said inert gas into a reusable storage device thereby depressurizing the sealed pressure vessel;
opening the pressure vessel and removing the metal filled sand mold; and
extracting the desired object from the sand mold.
6. The method of claim 5 wherein withdrawing the inert gas from the sealed pressure vessel may include filtering and separating unwanted gaseous compounds prior to transferring the said inert gas into a reusable storage device.
7. A method of casting a metal alloy comprising the following steps:
forming a sand based mold having the appropriate geometry to generate a desired object to be cast;
filling the sand based mold with a molten metal alloy;
placing the sand based mold in an open pressure vessel;
immediately thereafter closing and pressure sealing the pressure vessel;
pressurizing the sealed pressure vessel with an inert gas for a predetermined measured time;
said predetermined measured time sufficient for the molten metal to cool and solidify;
withdrawing the inert gas from the sealed pressure vessel and transferring said inert gas into a reusable storage device thereby depressurizing the sealed pressure vessel;
opening the pressure vessel and removing the metal filled sand mold; and
extracting the desired object from the sand mold.
8. The method of claim 7 wherein withdrawing the inert gas from the sealed pressure vessel may include filtering and separating unwanted gaseous compounds prior to transferring the said inert gas into a reusable storage device.
9. A method to reduce porosity defects in sand casted metal objects comprising:
forming a sand based mold having the appropriate geometry to generate a desired object to be cast;
placing the sand based mold in an open pressure vessel;
filling the sand based mold with a molten metal alloy;
immediately thereafter closing and pressure sealing the pressure vessel;
pressurizing the sealed pressure vessel with an inert gas for a predetermined measured time;
said predetermined measured time sufficient for the molten metal to cool and solidify;
depressurizing the sealed pressure vessel;
opening the pressure vessel and removing the metal filled sand mold; and
extracting the desired object from the sand mold.
10. A method to reduce porosity defects from mold-metal interface reactions comprising:
forming a sand based mold having the appropriate geometry to generate a desired object to be cast;
placing the sand based mold in an open pressure vessel;
filling the sand based mold with a molten metal alloy;
immediately thereafter closing and pressure sealing the pressure vessel;
pressurizing the sealed pressure vessel with an inert gas for a predetermined measured time;
said predetermined measured time sufficient for the molten metal to cool and solidify;
depressurizing the sealed pressure vessel;
opening the pressure vessel and removing the metal filled sand mold; and
extracting the desired object from the sand mold.
11. A method to improve the tensile strength, yield strength, and percent elongation of a sand casting comprising the following steps:
forming a sand based mold having the appropriate geometry to generate a desired object to be cast;
placing the sand based mold in an open pressure vessel;
filling the sand based mold with a molten metal alloy;
immediately thereafter closing and pressure sealing the pressure vessel;
pressurizing the sealed pressure vessel with an inert gas for a predetermined measured time;
said predetermined measured time sufficient for the molten metal to cool and solidify;
depressurizing the sealed pressure vessel;
opening the pressure vessel and removing the metal filled sand mold; and
extracting the desired object from the sand mold.
12. A method to reduce hazardous air pollutants in a sand casting process comprising:
forming a sand based mold having the appropriate geometry to generate a desired object to be cast;
placing the sand based mold in an open pressure vessel;
filling the sand based mold with a molten metal alloy;
immediately thereafter closing and pressure sealing the pressure vessel;
pressurizing the sealed pressure vessel with an inert gas for a predetermined measured time;
said predetermined measured time sufficient for the molten metal to cool and solidify;
depressurizing the sealed pressure vessel;
reclaiming and purifying the inert gas during the said depressurizing;
releasing non-hazardous by-products separated from the inert gas back into the atmosphere;
containing hazardous by-products separated from the inert gas;
opening the pressure vessel and removing the metal filled sand mold; and
extracting the desired object from the sand mold.

13. A device for casting a metal alloy comprising the following elements:
   a pressure vessel head;
   a pressure vessel base incorporating a surface to support a sand casting mold;
   a vertical travel guide in mechanical communication with the pressure vessel head and the pressure vessel base;
   said pressure vessel head and pressure vessel base incorporating interlocking members capable of forming a pressure seal when interlocked; and
   an actuator capable of engaging the interlocking members thereby forming a pressure seal when the pressure vessel head is in mechanical communication with the pressure vessel base.

14. The device of claim 13 wherein the pressure vessel base incorporates a unidirectional valve device to receive an inert gas from an external source.

15. The device of claim 13 wherein the pressure vessel base incorporates a bidirectional valve device with the means to receive an inert gas from an external source and exhaust said inert gas into an external source for later reuse.

16. A method of casting a metal alloy comprising the following steps:
   forming a sand based mold having the appropriate geometry to generate a desired object to be cast;
   placing the sand based mold in an open pressure vessel;
   filling the sand based mold with a molten metal alloy;
   immediately thereafter closing and pressure sealing the pressure vessel;
   pressurizing the sealed pressure vessel with helium for a predetermined measured time;
   said predetermined measured time sufficient for the molten metal to cool and solidify;
   depressurizing the sealed pressure vessel;
   opening the pressure vessel and removing the metal filled sand mold; and
   extracting the desired object from the sand mold.

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